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(54) Solid State Imaging Device and method of Manufacturing the same

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Specification

1. Title of the Invention

Solid State Imaging Device and Method of Manufacturing the Same

2. Scope of Claim for a Patent

(1) A solid state imaging device comprising a transparent substrate (5), a one conductivity type layer (4) that is formed on a first surface of the transparent substrate, and an other conductivity type region (3) that forms a pn junction with the one conductivity type layer, thereby to detect an

infrared ray incident from a surface opposite from the first surface of the transparent substrate based on a photoelectric transfer of the pn junction, the solid state imaging device further comprising

a thin film (6) formed on a second surface at the opposite side of the first surface of the transparent substrate (5), wherein

the transparent substrate is used as a part of a non-reflecting film formed together with the thin film.

(2) The solid state imaging device according to claim 1, wherein when refractive indexes of the thin film, the transparent film, and the one conductivity type layer are n1, n2, and n3 respectively, $n2 / n1 = -\sqrt{n3}$.

(3) The solid state imaging device according to claim 1 or 2, further comprising a groove (20) that is formed on the one conductivity type layer and the transparent substrate respectively, and separates each pn junction.

(4) The solid state imaging device according to any one of claims 1 to 3, further comprising individual apertures (7) each having a predetermined open area ratio relative to each pn junction on the thin film.

(5) A method of manufacturing a surface incidence type solid state imaging device comprising

a transparent substrate (5), a one conductivity type layer (4) that is formed on a first surface of the transparent substrate, an other conductivity type region (3) that forms a pn junction with the one conductivity type layer, and a thin film (6) formed on a second surface at the opposite side of the first surface of the transparent substrate, thereby to detect an infrared ray incident from the thin film side, the method comprising:

a step of forming a groove (20) that pierces through the one conductivity type layer to reach a predetermined depth of the transparent substrate, thereby to separate each pn junction;

a step of forming a stopper (21) on the bottom of the groove;

a step of removing the transparent substrate up to a predetermined film thickness equivalent to the predetermined depth prescribed by the stopper; and

a step of forming the thin film on the transparent substrate having the predetermined film thickness.

3. Detailed Description of the Invention

(Summary)

The present invention relates to a rear surface incidence type solid state imaging device that

detects an infrared ray, and a method of manufacturing this device, and

the invention has an object of preventing a mixture of signals between pixels due to an infrared ray that is multiply reflected within the transparent substrate.

The solid state imaging device comprises a transparent substrate, a one conductivity type layer that is formed on a first surface of the transparent substrate, and an other conductivity type region that forms a pn junction with the one conductivity type layer, thereby to detect an infrared ray incident from a surface opposite from the first surface of the transparent substrate based on a photoelectric transfer of the pn junction, the solid state imaging device further comprising a thin film formed on a second surface at the opposite side of the first surface of the transparent substrate, wherein the transparent substrate is used as a part of a non-reflecting film formed together with the thin film.

[Field of Industrial Utilization]

The present invention relates to a solid state imaging device, and a method of manufacturing this device, and relates, more particularly, to a rear surface incidence type solid state imaging device that detects an infrared ray, and a method of

manufacturing this device.

[Prior Art]

Fig. 6 is an illustration of a main portion of a conventional rear surface incidence type solid state imaging device. In the drawing, 100 denotes a non-reflection film, 101 denotes a CdTe epitaxial layer as a transparent substrate, 102 denotes a p-type HgCdTe layer, 103 denotes an n^+ type region, 104 denotes an insulation film, and 105 denotes an electrode. An infrared ray is incident from the infrared transparent CdTe epitaxial layer 101 via the non-reflection film 100. The infrared ray is detected based on a photoelectric transfer of the pn junction formed by the p-type HgCdTe layer 102 and the n^+ type region 103.

The CdTe epitaxial layer 101 is relatively thick of usually about 1 mm. Therefore, as indicated by IR in Fig. 6, an infrared ray that is multiply reflected within the CdTe epitaxial layer 101 is detected by an adjacent pn junction. In this case, signals are mixed between pixels. To avoid this problem, it is considered to provide individual apertures that firm up each pixel on the non-reflection film 100 so as not to detect the multiply reflected infrared ray by the adjacent pn junction. However, as the CdTe epitaxial layer 101 is

relatively thick of about 1 mm, it is impossible to arrange such that the multiply reflected infrared ray is not detected at all by the adjacent pn junction. The mixing of signals between the pixels cannot be avoided.

In general, a solid state imaging device using HgCdTe / CdTe is used at a low temperature. However, the coefficient of thermal expansion of HgCdTe / CdTe is large different from the coefficient of thermal expansion of silicon (Si). Therefore, when the film thickness of HgCdTe / CdTe is large, a clearance occurs within the device, which is not preferable. Accordingly, there is a limit to increasing the size of a chip according to the number of pixels, depending on the difference between the coefficients of thermal expansion.

[Problems that the Invention is to Solve]

Therefore, the conventional device has a problem that the infrared ray that is multiply reflected within the transparent substrate is detected by the adjacent pn junction, and has the problem that signals are mixed within the pixels.

It is an object of the present invention to provide a solid state imaging device and a method of manufacturing this device that can prevent a mixture of signals between pixels due to an infrared ray that

is multiply reflected within the transparent substrate.

[Means for Solving the Problems]

The above object can be achieved by the solid state imaging device and the method of manufacturing this device, the device comprising a transparent substrate, a one conductivity type layer that is formed on a first surface of the transparent substrate, and an other conductivity type region that forms a pn junction with the one conductivity type layer, thereby to detect an infrared ray incident from a surface opposite from the first surface of the transparent substrate based on a photoelectric transfer of the pn junction, the solid state imaging device further comprising a thin film formed on a second surface at the opposite side of the first surface of the transparent substrate, wherein the transparent substrate is used as a part of a non-reflecting film formed together with the thin film.

(Operation)

In the present invention, as the transparent substrate is used as a part of the non-reflection film, the film thickness of the transparent film can be made thin.

Therefore, the detection of the infrared ray

that is multiply reflected within the transparent substrate by the adjacent pn junction can be prevented. Accordingly, the mixing of signals within the pixels can be prevented.

[Embodiment]

Fig. 1 is an illustration of a main portion of the device according to the first embodiment of the present invention. In the drawing, 1 denotes an electrode, 2 denotes an insulation film, 3 denotes an n^+ type region, 4 denotes a p-type HgCdTe layer, 5 denotes a CdTe epitaxial layer, and 6 denotes a KBr thin film. In the present embodiment, both the CdTe epitaxial layer 5 and the thin film 6 are as thin as 2.5 μm. The CdTe epitaxial layer 5 as the transparent substrate structures a non-reflection film together with the KBr thin film 6. Conventionally, signals are mixed between pixels, as the transparent substrate has a large thickness. In order to solve this problem, the transparent substrate has a small thickness, and is used as a part of the non-reflection film.

As shown in Fig. 2, when first to third layers 11 to 13 have refractive indexes n1 to n3, a reflection coefficient of R can be obtained as follows:

$$R = \{(n1^2\, n3 - n2^2) / (n1^2\, n3 + n2^2)\}^2$$

Therefore, in the reflection prevention film using two layers, a condition for non-reflection is $n1^2 n3 - n2^2 = 0$. In other word, $n2 / n1 = \sqrt{n3}$. When the wavelength is λ, the film thickness of the first and second layers is $m\lambda / 4$ (where, m = 1, 3, 5, ...).

In the first embodiment, when λ = 10 μm, the first to third layer 11 to 13 corresponds to the layer 6 to 4 in Fig. 1 respectively, therefore n3 (HgCdTe) = 3.5, n2 (CdTe) = 2.8, and $n1 = n2 / n1 = \sqrt{n3} = 1.50$. In the first embodiment, KBr having a refractive index 1.53 is used as a material that has a refractive index near to 1.50 and transmits the infrared ray. As the film thick is 2.5 μm, there is no particular problem in manufacturing the film. It is needless to mention that NaCl having a refractive index of 1.53 and SiO_2 having a refractive index of 1.49 can also be used in addition to KBr.

As explained above, according to the present embodiment, as the transparent substrate can be made thin, the mixture of signals between pixels by the infrared ray that is multiply reflected within the transparent substrate can be prevented. Further, the problem that occurs due to the difference between the coefficients of thermal expansion can be reduced, because of the thin transparent substrate.

Fig. 3 is an illustration of a device according to the second embodiment of the present invention.

As shown in Fig. 3, individual apertures 7 are provided to separate pixels on the KBr thin film 6, thereby to securely prevent the mixing of signals between pixels. In Fig. 3, portions identical with those in Fig. 1 are assigned with like reference numerals, and the explanation of these portions is omitted.

The manufacturing method according to the second embodiment will be explained next. The p-type HgCdTe layer 4 is formed on the CdTe epitaxial layer (transparent substrate) 5. The n^+ type region 3 is formed on the p-type HgCdTe layer 4 by using an ion injection technique, thereby to form a pn junction. The insulation film 2 as a protection film and the electrode 1 are formed. After that, the CdTe epitaxial layer 5 is ground and is made thin using a chemical etching until when the film thickness becomes 2.5 μm. Further, the KBr thin film 6 is deposited on the CdTe epitaxial layer 5, thereby to form a non-reflection film. Finally, in order to obtain a predetermined light quantity, the individual apertures 7 having a prescribed aperture relative to each pn junction (that is, each pixel) are formed on the KBr thin film 6. The individual apertures 7 are formed using Cr / Al, for example. The infrared ray is not reflected on the individual apertures 7.

When the pitch between pixels becomes very

small along the increase in the number of pixels, the mixture of signals could occur between the pixels due to the infrared ray that is multiply reflected within the transparent substrate even if the transparent substrate is thin like in the first and second embodiments.

Embodiments that can solve this problem will be explained next.

First, a method according to one embodiment of the present invention will be explained with reference to Fig. 4. In Fig. 4, portions substantially identical with those in Fig. 1 are assigned with like reference numerals, and the explanation of these portions is omitted. The process up to before the grinding of the CdTe epitaxial layer 5 and thinning this layer using the chemical etching in the manufacturing method according to the second embodiment is substantially the same as that in the present embodiment. However, before grinding the CdTe epitaxial layer 5, the grooves 20 are formed on the p-type HgCdTe layer 4 and the CdTe epitaxial layer 5. The groove 20 pierces through the p-type HgCdTe layer 4 to reach the CdTe epitaxial layer 5 by the depth of $m\mu/4$. Next, a stopper 21 such as SiO_2 and Si_2N_4 having a larger hardness than that of CdTe is formed on the bottom of the groove 20. The CdTe epitaxial layer 5

is ground to thin the layer to have the film thickness of $m\lambda/4$ indicated by a broken line. After that, the KBr thin film 6 is formed on the CdTe epitaxial layer 5. In the present embodiment, the stopper 21 stops the grinding of the CdTe epitaxial layer 5 accurately at the position of the film thickness of $m\mu/4$. Therefore, in setting the CdTe epitaxial layer 5 is to a small thickness of 2.5 μm, the layer can be securely and uniformly thinned.

According to the present embodiment, each pixel is isolated completely by forming the groove 20. Therefore, the mixing of signals between the pixels can be completely prevented.

Fig. 5 is an illustration of a main portion of the device according to the third embodiment of the present invention. In Fig. 5, portions substantially identical with those in Fig. 3 and Fig. 4 are assigned with like reference numerals, and the explanation of these portions is omitted. In the present embodiment, an ohmic contact 22 made of Au, for example, is provided between the stopper 21 and the insulation film 2. The individual apertures 7 need not necessarily be provided. However, in the present embodiment, the thin CdTe epitaxial layer 4, the grooves 20, and the individual apertures 7 are provided. Therefore, the mixing of signals between pixels can be completely prevented.

While the embodiments of the present invention are explained above, the present invention can be variously modified according to the gist of the present invention, and these modifications are not excluded from the present invention.

[Effects of the Invention]

According to the present invention, the transparent substrate is thinned, and is utilized as a part of the non-reflection film. Therefore, the mixture of signals between pixels due to the detection of the infrared ray that is multiply reflected within the transparent substrate by the adjacent pn junction can be prevented. Therefore, the present invention is extremely practically effective.

4. Brief Description of the Drawings

Fig. 1 is a cross-sectional view of a main portion of the device according to the first embodiment of the present invention;

Fig. 2 is an explanatory view of a reflection prevention film using two layers;

Fig. 3 is a cross-sectional view of a main portion of the device according to the second embodiment of the present invention;

Fig. 4 is an explanatory view of the method

according to one embodiment of the present invention;

Fig. 5 is a cross-sectional view of a main portion of the device according to the third embodiment of the present invention; and

Fig. 6 is a cross-sectional view of a main portion of the conventional device.

In Fig. 1 to Fig. 5,

1 denotes an electrode,

2 denotes an insulation film,

3 denotes an n^+ type region,

4 denotes a p-type HgCdTe layer,

5 denotes a CdTe epitaxial layer,

6 denotes a KBr thin film,

7 denotes an individual aperture,

11 denotes a first layer,

12 denotes a second layer,

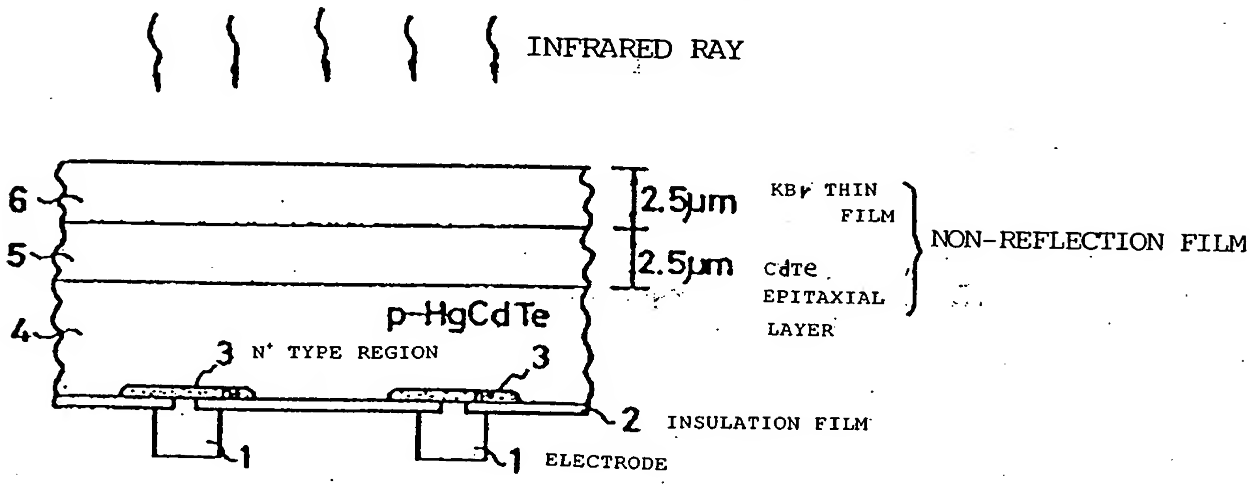
13 denotes a third layer,

20 denotes a groove,

21 denotes a stopper, and

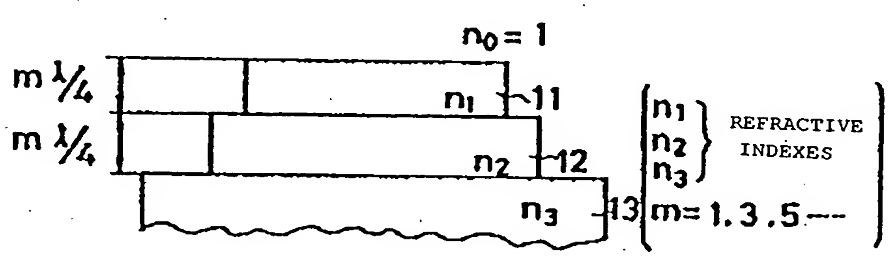
22 denotes an ohmic contact.

FIG. 1



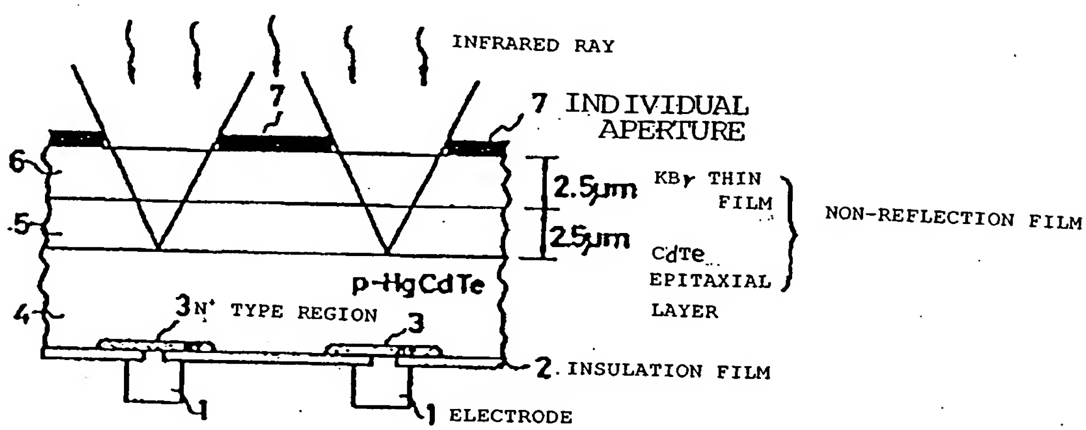
CROSS-SECTIONAL VIEW OF MAIN PORTION OF DEVICE ACCORDING TO FIRST EMBODIMENT OF PRESENT INVENTION

FIG. 2



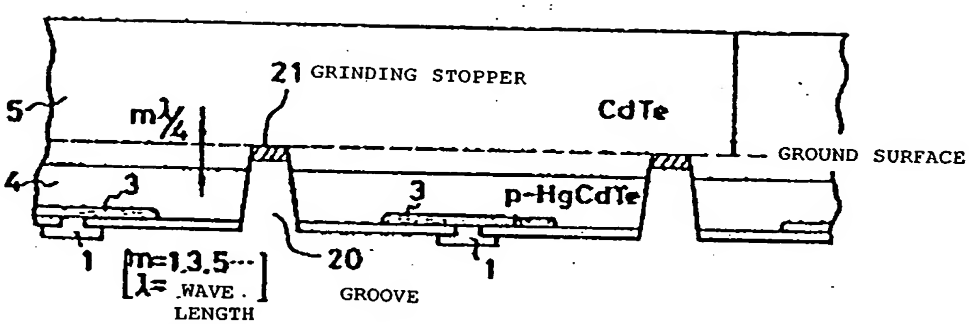
EXPLANATORY VIEW OF REFLECTION PREVENTION FILM USING TWO LAYERS

FIG. 3



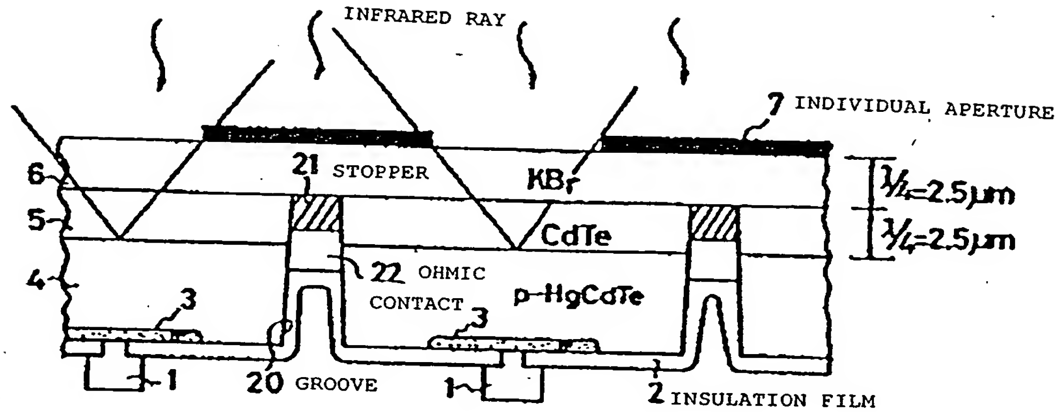
CROSS-SECTIONAL VIEW OF MAIN PORTION OF DEVICE ACCORDING TO SECOND EMBODIMENT OF PRESENT INVENTION

FIG. 4



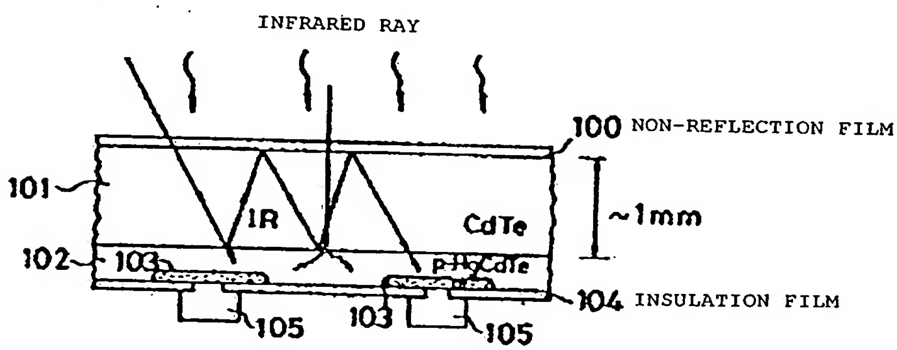
EXPLANATORY VIEW OF METHOD ACCORDING TO ONE EMBODIMENT OF PRESENT INVENTION

FIG. 5



CROSS-SECTIONAL VIEW OF MAIN PORTION OF DEVICE ACCORDING TO THIRD EMBODIMENT OF PRESENT INVENTION

FIG. 6



CROSS-SECTIONAL VIEW OF MAIN PORTION OF CONVENTIONAL DEVICE